भारतीय मानक
Indian Standard

IS 17128 (Part 1) : 2019

स्वचल वाहन — वाहन गतिकी परीक्षण पद्धतियाँ

भाग 1 सामान्य परीक्षण परिस्थितियाँ

Automotive Vehicles — Vehicle Dynamics Test Methods

Part 1 General Test Conditions

ICS 43.020

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Automotive Braking and Steering System, Vehicle Testing and Performance Evaluation Sectional Committee, TED 04

FOREWORD

This Indian Standard was adopted by the Bureau of Indian Standards, after the draft finalized by the Automotive Braking and Steering System, Vehicle Testing and Performance Evaluation Sectional Committee had been approved by the Transport Engineering Division Council.

The dynamic behavior of a road vehicle is a most important part of vehicle safety. Any given vehicle, together with its driver and the prevailing environment, forms a unique closed-loop system. The task of evaluating dynamic behavior is therefore very difficult since there is a significant interaction between these driver-vehicle-environment elements, each of which is complex in itself. A complete and accurate description of the behavior of the road vehicle must necessarily involve information obtained from a number of tests of different types. Since they quantify only a small part of the complete vehicle handling characteristics, the results of these tests can only be considered significant for a correspondingly small part of the overall dynamic behavior.

Less data is acquired to obtain relationship between overall vehicle dynamic properties vs actual driving patterns. The effort is going on to do obtain correlation between accident avoidance and vehicle dynamic properties in general. Therefore, it is not possible to use this standard for regulatory purposes. Finally, test conditions and tyres have a strong influence on test results. Only vehicle dynamic properties obtained under identical test and tyre conditions are comparable.

This Indian Standard is published in several parts. The other parts in this series are:

Part 2	Steady state test procedures
Part 3	Transient response test methods
Part 4	Ride comfort measurements
Part 5	Subjective evaluation -vehicle ride, handling, steering and tyre evaluation

In the preparation of this standard considerable assistance has been derived from the following International Standards:

a) ISO 4138 : 2004 Passenger cars — Steady state circular driving behaviour — Open loop test methods

b) ISO 7401 : 2003 Road vehicles — Lateral transient response test methods — Open loop test methods

c) ISO 7975 : 2006 Passenger cars — Braking in a turn — Open loop test method

d) ISO/TR 8725 : 1988 Road vehicles — Transient open loop response test method with one period of sinusoidal input

e) ISO/TR 8726 : 1988 Road vehicles — Transient open loop response test method with pseudo-random steering input

f) ISO 9815 : 2003 Road vehicles — Passenger car and trailer combinations — lateral stability test

g) ISO 12021-1: 1996 Road vehicles — Sensitivity to lateral wind — Part 1: Open loop test method using wind generator input

h) ISO 15037-1 : 2006 Road vehicles — Vehicle dynamics test methods — Part 1: General conditions for passenger cars

j) ISO 17288-2 : 2004 Passenger cars — Free steer behaviour — Part 2: Steering pulse open-loop test method

For the purpose of deciding whether a particular requirement of this standard is complied with the final value, observed or calculated, expressing the result of test or analysis shall be rounded off in accordance with IS 2 : 1960 ‘Rules for rounding off numerical values (*revised*)’. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

Indian Standard

AUTOMOTIVE VEHICLES — VEHICLE DYNAMICS TEST METHODS

PART 1 GENERAL TEST CONDITIONS

1 SCOPE

1.1 This standard (Part 1) specifies general test conditions that apply when vehicle dynamics measurements to be carried out for M1 categories of vehicles as defined in IS 14272.

1.2 This standard specifies the general conditions for vehicle parameters, measuring equipment, data processing, environment (that is, test track, wind velocity, climate conditions), vehicle preparation for loading conditions, Vehicle readiness and Test report preparation (general data and test conditions).

1.3 This standard provides guidelines for various test methods used to evaluate vehicle properties and not for any regulatory requirements.

2 REFERENCES

The standard indicated below contain provisions, which through reference in this text, constitute provisions of this standard. At the time of publication the edition indicated was valid. All standards are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below:

IS No.	*Title*
14272 : 2011	Automotive vehicles — Types — Terminology (*first revision*)

3 VARIABLES

3.1 Reference System

The variables of motion to describe vehicle behavior in a test-specific driving situation shall be referred to vehicle axis system (X,Y,Z). Vehicle fixed co-ordinate system (Xx, Yy, Zz) to be used. CG of the vehicle in testing condition shall be taken as the reference point.

In case CG point not taken as reference, other specific geometry point on the vehicle near to the CG point to be taken for the measurement and co-related with respect to CG point.

3.2 Abbreviation

Xx — Along longitudinal axis of vehicle, origin at CG point (postive towards front).

Yy — Along lateral axis of vehicle, origin at CG point (postive towards driver left).

Zz — Along vertical axis of vehicle, origin at CG point (postive upwards).

Roll angle (RXx) — Rotation about X-axis of vehicle (anti clockwise positive from front view of vehicle).

Pitch angle (RYy) — Rotation about Y-axis of vehicle (anti clockwise positive from left view of vehicle).

Yaw angle (RZz) — Rotation about Z-axis of vehicle (anti clockwise positive from top view of vehicle).

3.3 Parameters to be Measured

3.3.1 *Static Parameters*

Following static parameters to be measured (*see* Fig. 1 and Fig. 2):

a) Wheel base (l) — Distance between the front tyre center to rear tyre center in the side view of the vehicle;
b) Wheel track — Front (T_f) — Distance between front left tyre center to front right tyre center in the front view of the vehicle;
c) Wheel track — Rear (T_r) — Distance between rear left tyre center to rear right tyre center in the rear view of the vehicle;
d) Center of gravity of vehicle, CG — Point at which entire weight of the vehicle acts:
    1) Longitudinal — From front axle centerline,
    2) Lateral — From vehicle geometric centerline,
    3) Vertical (h) — Height from ground level.
e) Static Stability factor (SSF) — The static stability Factor of a vehicle is one half the track width, T_f, divided by h, the height of the center of gravity above the road;
f) Front axle weight (FAW) — A part of the total mass of vehicle acting at front axle of the vehicle; and
g) Rear axle weight (RAW) — A part for the total mass of vehicle acting at rear axle of the vehicle.

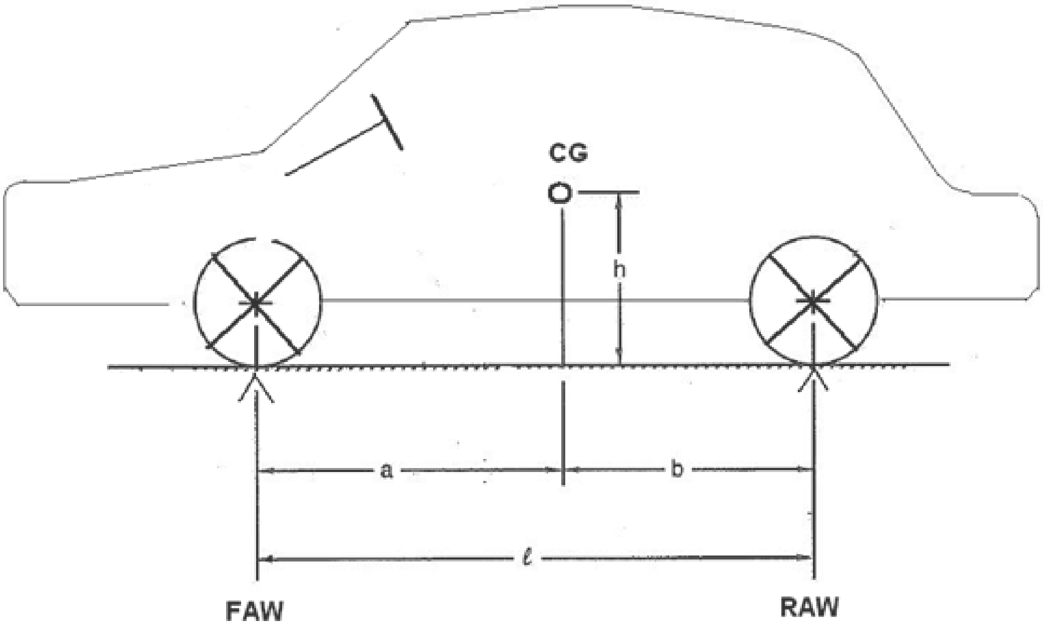


Fig. 1 Static Parameters to Be Measured (Front View)

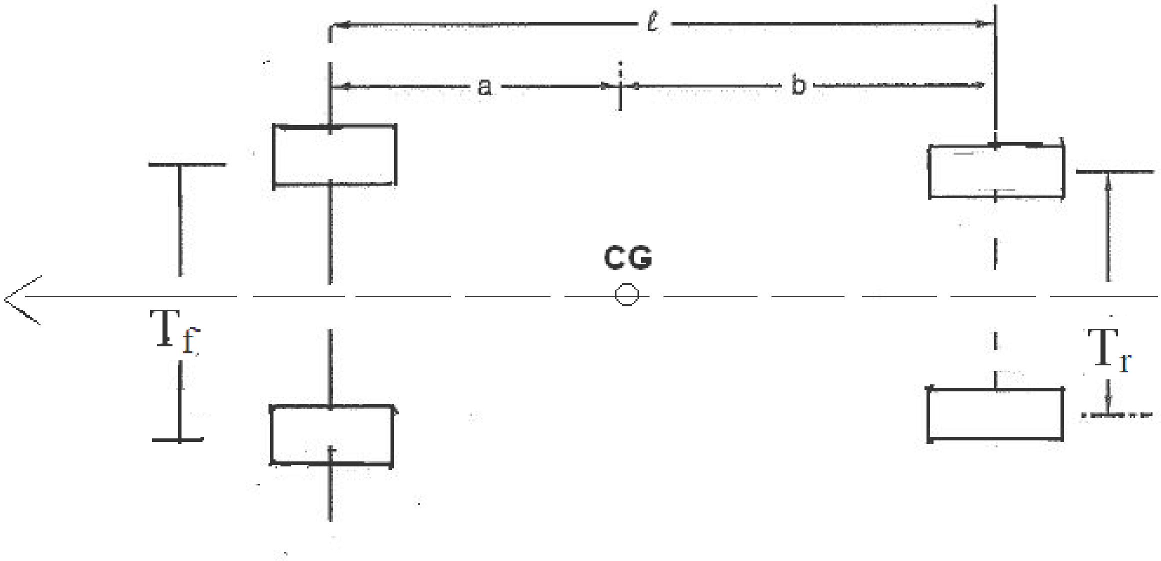


Fig. 2 Static Parameters to Be Measured (Top View)

3.3.2 *Dynamic Parameters*

3.3.2.1 *Linear variables*

a) Longitudinal Velocity (v_x) — Rate of change of linear displacement of vehicle in the direction of X-axis at reference point.

b) Longitudinal acceleration (a_x) — Rate of change of linear velocity of vehicle in the direction of X-axis at reference point.

c) Lateral Velocity (v_y) — Rate of change of linear displacement of vehicle in the direction of Y-axis at reference point.

d) Lateral acceleration (a_y) — Rate of change of linear velocity of vehicle in the direction of Y-axis at reference point.

3.3.2.2 *Rotational motion*

a) Vehicle Roll angle (φv) — Vehicle rotational angle about longitudinal (Xx) axis, origin at reference point.

b) Pitch angle (θ) — Vehicle rotational angle about lateral (Yy) axis, origin at reference point.

c) Yaw angle (ψ) — Vehicle rotational angle about verticle (Zz) axis, origin at reference point.

3.3.2.3 *Rotational velocity*

a) Roll velocity (dφv/dt) — Rate of change of vehicle roll angle at reference point.

b) Pitch velocity (dθ/dt) — Rate of change of vehicle pitch angle at reference point.

c) Yaw velocity (dψ/dt) — Rate of change of vehicle yaw angle at reference point.

3.3.2.4 *Other dynamic parameters*

a) Front tyre slip angle (α_f) — Front tyre slip angle is the angular difference between the direction the front tyre contact patch with the road is pointing and the direction of the wheel.

b) Rear tyre slip angle (α_r) — Rear tyre slip angle is the angular difference between the direction the Rear tyre contact patch with the road is pointing and the direction of the wheel.

c) Body Side slip angle (β) — Angle from the X-axis to the direction of the horizontal velocity about the Z-axis .

d) Steering wheel angle (δ_H) — Angular displacement of steering wheel measured from straight ahead position. Counter Clock wise rotation is positive.

e) Steering wheel torque (M_H) — Torque applied for rotating steering wheel about its own axis. Rotation towards left is positive.

f) Path radius (R) — Distance between vehicle trajectory point & instantaneous center.

3.3.2.5 *Understeer gradient (K)*

It is the difference between the front side slip angle to rear side slip angle (α_f - α_r). The steady-state handling characteristics may be classified into three categories:

For understeer : ($\alpha_f > \alpha_r$), K = positive

For neutral steer : ($\alpha_f = \alpha_r$), K = 0

For oversteer : ($\alpha_f < \alpha_r$), K = Negative

3.3.2.5.1 *Understeer*

When the understeer coefficient K > 0, which is equivalent to the slip angle of the front tyre αf being greater than that of the rear tyre αr, (that is, $\alpha_f > \alpha_r$), the steer angle required to negotiate a given curve increases with the square of vehicle forward speed.

For an understeer vehicle, a characteristic speed vchar may be identified. It is the speed at which the steer angle required to negotiate a turn is equal to 2*l/R, as shown in the Fig. 3.

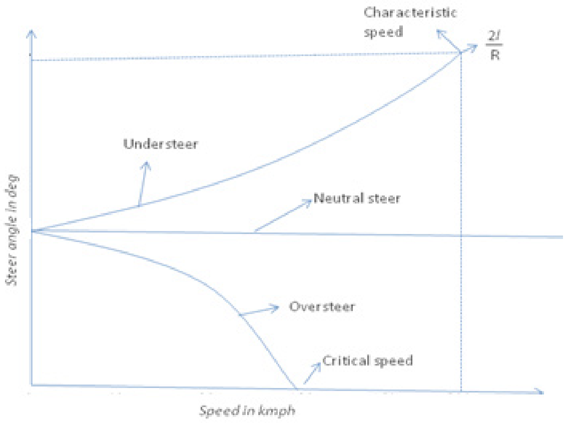


FIG. 3 UNDER STEER GRADIENT

3.3.2.5.2 *Neutral steer*

When the under steer coefficient K = 0, which is equivalent to the slip angles of the front and rear tyres bring equal that is, $\alpha_f = \alpha_r$), the steer angle required to negotiate a given curve is independent of forward speed.

3.3.2.5.3 *Oversteer*

When the understeer coefficient K which is equivalent to the slip angle of the front tyre αf being less than that of the rear tyre αr (that is, $\alpha_f < \alpha_r$), the steer angle required to negotiate a given curve decreases with the increase of vehicle forward speed.

For all oversteer vehicle, a critical speed vchar, can be identified. It is the speed at which the steer angle required to negotiate any turn is zero.

NOTE — For specific parameter to be measured, refer the relevant part of this Indian Standard. These variables can be measured directly or can be calculated from relevant measured parameters.

4 MEASURING EQUIPMENT

4.1 Description

Typical operating range and accuracy level of system and transducers is shown in Table 1. Appropriate transducers and data recording system to be used for the data collection with time histories. All data to be collected on multi channel recording system in time domain. The below specified accuracies shall be achieved whether the variables are measured or are calculated.

4.2 Transducers and Installations

Transducers shall be installed in line to manufacturer's recommendations/instructions. So that desired variable can be directly measured. If it is not possible to measure the desired variable at intended position then transformation to be carried out to calculate the desired variable.

4.3 Data Processing

The frequency range relevant tests on dynamics of passenger cars is between 0 to 5Hz. Based on whether analogue or digital data processing methods are used,

4.3.1 *Analogue Data Processing*

The bandwidth of the entire, combined transducer/recording system shall be no less than 8 Hz. In order

Table 1 Variable's typical Range and Recommended Error

(*Clause* 4.1)

Sl No.	Variable	Typical operating Range	Recommended Max 'Overall' Error
(1)	(2)	(3)	(4)
i)	Steering wheel angle	-360° to +360°	± 1° for < 90° ± 2° for > 90° and < 360° ± 4° for > 360°
ii)	Steering wheel torque (M_H)	-30 N.m to +30 N.m	± 0,1 Nm for M_H < 10 Nm ± 0,3 Nm for M_H > 10 Nm
iii)	Sideslip angle	-20° to +20°	+/-0.3°
iv)	Longitudinal velocity	0 to 180 km/h	± 1 km/h for v_x < 100 km/h ± 2 km/h for v_x > 100 km/h
v)	Lateral velocity	-10 m/s to +10 m/s	+/-0.2m/s
vi)	Longitudinal acceleration	-15m/s^{2}to +15m/s^2	+/-0.15m/s^2
vii)	Lateral acceleration	-15m/s^{2}to +15m/s^2	+/-0.15m/s^2
viii)	Roll angle	-15° to +15°	+/-0.15°
ix)	Pitch Angle	-15° to +15°	+/-0.15°
x)	Yaw Angle	-30° g to +30°	+/-0.30°
xi)	Yaw velocity	-50° /s to +50° /s	± 0,3°/s for < 20°/s ± 1°/s for > 20°/s
xii)	Pitch Velocity	-50° /s to +50° /s	± 0,3°/s for < 20°/s ± 1°/s for > 20°/s
xiii)	Roll Velocity	-50° /s to +50° /s	± 0,3°/s for < 20°/s ± 1°/s for > 20°/s
xiv)	Vertical displacement	+/- 0.1m	+/-.001m
xv)	Vertical acceleration	-30m/s^{2}to +30m/s^2	+/-0.15m/s^2

to execute the necessary filtering of signals, low-pass filters shall be employed. The width of the passband (from 0 Hz to frequency *f*0 at -3 dB) shall not be less than 9 Hz. Amplitude errors shall be less than ± 0.5 percent in the relevant frequency range of 0 Hz to 5 Hz. All analog signals shall be processed with filters having phase characteristics sufficiently similar to ensure that time delay differences due to filtering lie within the required accuracy for time measurement.

4.3.2 *Digital Data Processing General Considerations*

Preparation of analog signals includes consideration of filter amplitude attenuation and sampling rate to avoid aliasing errors, and filter phase lags and time delays. Sampling and digitizing considerations include presampling amplification of signals to minimize digitization errors, number of bits per sample, number of samples per cycle, sample and hold amplification, and timewise spacing of samples. Considerations for additional phase less digital filtering include selection of passbands and stopbands, and the attenuation and allowable ripple in each, as well as correction of antialias filter phase lags. Each of these factors must be considered if an overall data acquisition accuracy of ± 0.5 percent is to be achieved.

5 TEST CONDITIONS

5.1 General

Below is the guidelines for ambient and vehicle test conditions to be maintained. Any deviations, needs to be recorded in reports.

5.2 Test Track

Test to be carried out on smooth, dry, clean and uniform paved road surface. The gradient of the paved road surface should not exceed more than 2 percent in any direction when measured over any distance interval between that corresponding to vehicle track and 25 m. For each test, road surface condition and paving material shall be recorded in the test report.

It is recommended to have road gradient less than 1.5 percent in any direction.

5.3 Climate Condition

The ambient wind velocity shall not exceed 5 m/s during test. For each test method, wind velocity, direction and climate conditions shall be recorded.

5.4 Test Vehicle

5.4.1 *General Data*

General data of the test vehicle shall be presented in the test report shown in Annex A. For any change of vehicle specification (that is, load etc), general data shall be recorded again. For new vehicle it is recommended to have adequate initial run-in before starting the tests. In certain cases ambient temp has a significant influence on the test results, this should be taken in to account when making comparisons between vehicles.

5.4.2 *Tyres*

5.4.2.1 *General*

For a general tyre condition, new tyre shall be fitted inline to vehicle manufacturer's specifications. If not specified by the tyre manufacturer, they shall be run in for at least 150 kms on the test vehicle or an equivalent vehicle without excessively harsh use, for example braking, acceleration, cornering, hitting the kerb etc. After run in, the tyres shall be maintained at the same vehicle positions for the tests.

5.4.2.2 *Tread-depth*

Tyre tread depth shall have at least 90 percent of the original value across the whole breadth of the tread and around the whole circumference of the tyre. Tread depth shall be recorded in the test reports. It is preferred to measure tread depth at tread wear indicators on the tyre or to be measured at the same identified locations.

5.4.2.3 *Date of manufacturing*

Date of manufacturing, other regulatory markings on tyre, printed construction details should be recorded in test reports. The tyre used for testing should not have been manufactured before twelve months. The tyre side wall photographs may be attached to the report to capture manufacturing details of the tyres.

5.4.2.4 *Tyre pressure*

Tyres shall be inflated to the pressure as specified by the vehicle manufacturer for the test vehicle configuration at the ambient temperature of the test. Tolerance for setting the cold inflation pressure is ± 5 kPa (± 0.7 PSI) for the pressure up to 250 kPa (36 PSI) and ± 2 percent for the pressure above 250 kPa (36 PSI). Inflation pressure shall be recorded in test reports.

$$(1\ \text{kPa} = 10^{-2}\ \text{bar} = 10^{-3}\ \text{N/m}^2 = 0.145\,038\ \text{PSI})$$

5.4.2.5 *Others*

Tests may also be performed under conditions other than the general tyre conditions. The details shall be noted in the test reports. As the tread depth or uneven wear may have a significant influence on test results, it is recommended that those parameters to be taken into account when making comparisons between vehicles or between tyres.

5.4.3 *Operating Components*

If any specific part in the vehicle is replaced or the geometry of the vehicle is changed, shall be recorded, as this may have significant influence on measured data for example, suspenion parts, steering parts, brake parts, rubber mounts, etc or any other part which can change the vehicle weight distributions.

5.4.4 *Loading Conditions of the Vehicle*

The test mass shall be between the complete vehicle kerb mass plus driver, test equipment and the maximum total mass as specified by vehicle manufacturer. Care shall be taken to generate a minimum deviation in the location of the centre of gravity and in the moments of inertia as compared to the loading conditions of the vehicle in normal use. Resulting wheel loads shall be determined and recorded in the test report (Refer Annex A and Annex B). Care shall be taken if dummy mass is used for loading. Dummy shall represent the equivalent passenger mass.

6 TEST METHODS

6.1 Warm Up

All relevant vehicle components shall be warmed up prior to the tests in order to achieve component temperature representative of the normal driving conditions. Tyres shall be warmed up prior to the tests to achieve an equilibrium temperature and pressure representative of normal driving conditions.

A procedure equivalent to driving at the test speed for a distance of 10 km or driving 500 m at a lateral accelerations of 3 m/sec^2 both left and right turns, may be appropriate for warming up the tyres.

6.2 Initial Driving Condition

6.2.1 *General*

The initial driving condition is specified in most of the vehicle dynamics test methods. It can be either steady state straight run or steady state circular run.

If there is no specific requirement defined in a test method standard, the test shall be performed in the highest suitable gear for vehicles with manual transmission and for vehicles with automatic transmission in drive-D. The position of the transmission lever and the selected driving programme shall be recorded in the test report.

The position of the steering wheel and the accelerator pedal shall be kept as constant as possible during the initial driving condition. The moment of observation t_{ss} to evaluate steady state conditions is defined as the point in time which usually is between 0.5 s to 0.8 s before the reference point in time t0 of the specific test method. The initial condition is considered to be sufficiently constant if for the moment if observation t_{ss} the requirements of **6.2.2** and **6.2.3** are fulfilled.

NOTE — For the method which is used to determine only steady state values the moment of observation t_{ss} and the reference time t_0 will be identical.

6.2.2 *Steady State Straight Ahead Run*

The longitudinal velocity in the initial driving condition shall not deviate by more than + 1km/h (+ 2 km/h for the velocities more than 100 km/h) from the nominal value during the time interval from t_1 to t_2 and the mean value of lateral acceleration shall be within a range from + 0.3 m/s^2 as an alternative to the limits of lateral acceleration, the mean value of the yaw velocity shall be within a range from + 0.5° /s.

For the time interval from t_1 to t_2, the standard deviation of the lateral acceleration shall not exceed o.3 m/s^2. As an alternate to the limits of lateral acceleration, the standard deviation of the yaw velocity shall not exceed 0.5°/s.

The difference between the mean values of the longitudinal velocity during the time intervals t_1 to t_{ss} and t_{ss} to t_2 shall not exceed + 1 km/h (+ 2 km/h for the velocities exceed 100 km/h).

6.2.3 *Steady State Circular Run*

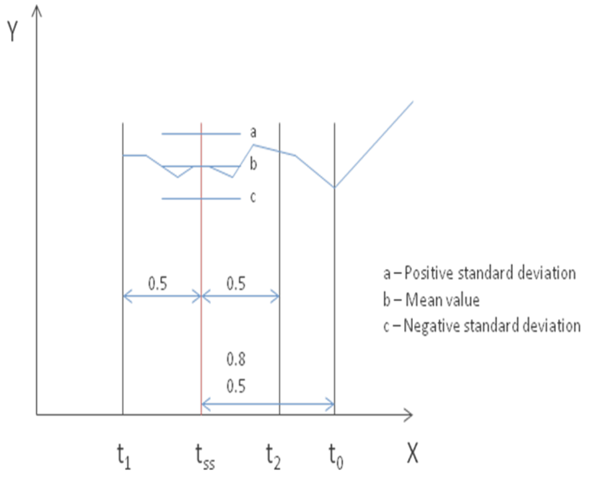
The initial radius R_0 shall be calculated as follows:

$$R_0 = v_{x,0}/(dc/dt)$$

$$R_0 = v_{x,0}/(dc/dt)$$

The radius in the initial driving condition shall not deviate by more than 2 percent or + 2 m from the nominal value during the time interval form t_1 to t_2.

As shown in the below Fig. 4, for the time interval t_1 to t_2, the standard deviation of the lateral acceleration shall not exceed 5 percent of its mean value and the standard deviation of the longitudinal velocity shall not exceed 3 percent of its mean value.



Terminologies:

X = time, s;

Y = measured variable;

t_0 = reference point in time of the specific test method;

t_1 = time measurement 1;

t_2 = time measurement 2; and

t_{ss} = moment of observation to evaluate steady state conditions.

FIG. 4 STANDARD DEVIATION OF THE LATERAL ACCELERATION

The difference between the mean values of the lateral acceleration during the time intervals t_1 to t_{ss} and t_{ss} to t_2 shall not exceed the nominal value of the lateral acceleration by more than 5 percent. The difference between the mean values of the longitudinal velocity during the time intervals t_1 and t_{ss} to t_2 shall not exceed the nominal value of longitudinal velocity by more than 3 percent.

For the time interval from t_1 to t_2, the mean value of the lateral acceleration shall not deviate from the nominal value by more than + 3 percent.

7 TRANSDUCERS AND THEIR INSTALLATIONS

7.1 General

Transducers of various types, some commercially available and some specially fabricated, are used in measuring the required and optional variables. If a transducer does not directly measure the required variable, appropriate adjustments shall be made to its signal to obtain the required variable with a sufficient level of accuracy. Because of the variety of instrumentation possibilities, the type of each instrument used shall be recorded; and where applicable, its location on the vehicle shall be entered on the test data sheets.

7.2 Steering-Wheel Angle

Steering-wheel angle is measured relative to the sprung mass. Typical transducers are multi-turn potentiometers or digital shaft encoders, geared to the back of the steering wheel or attached to a ‘second steering wheel’.

7.3 Longitudinal Velocity

A longitudinal velocity transducer should be installed as close as possible to the reference point position on the vehicle. The location of the velocity transducer shall be recorded and its signal corrected as necessary during data processing to provide longitudinal velocity at the reference point. Typical transducers are fifth wheels with accuracies to 0.2 km/h, and ‘contactless’ velocity transducers based upon optical or doppler principles, with optical accuracies to 0.1 km/h and doppler accuracies to 0.5 km/h. The steady-state fifth-wheel signal is very close to horizontal velocity, while optical transducers measure longitudinal velocity (the component of horizontal velocity in the X direction, equal to horizontal velocity multiplied by the cosine of the sideslip angle). An additional way to measure the longitudinal velocity is by Global Positioning System (GPS) sensor (*see* **7.11**).

7.4 Lateral Velocity and Sideslip Angle

Lateral velocity at a given point can be measured directly by means of a bipolar velocity transducer based upon optical principles, installed according to the manufacturer’s specifications. The location of the transducer must be recorded. Lateral velocity at any other point can be obtained by interpolation between two lateral velocity transducers or by extrapolation from the lateral velocity at the point of measurement, by adding the product of yaw velocity times the distance to the desired point. Sideslip angle is computed as the angle whose tangent is lateral velocity divided by longitudinal velocity. Commercially available bipolar velocity transducers have full-scale range of ± 10 m/s and ± 1 percent full-scale steady-state accuracy. Sideslip angle can be measured directly by a castered trolley, attached to the vehicle through gimbals and loading springs to keep the caster axis vertical. The sideslip angle measured is that which exists at the caster axis. The sideslip angle at any other point on the longitudinal axis of the vehicle can be computed from the sideslip angle at the point of measurement and the yaw velocity. The vehicle sideslip angle is defined as that obtained for the location of the origin of the vehicle axis system. At steady state, accuracies of 0.25° are possible using sideslip trolleys. Lateral velocity can also be computed by integration of lateral acceleration (corrected for position, roll angle, and surface inclination errors) minus the product of longitudinal velocity and yaw velocity. Sideslip angle is then computed. This method is suitable only for short tests because the net acceleration error, including zero offsets, is integrated.

7.5 Angular Velocity

Yaw, roll and pitch velocity are measured directly by angular-rate transducers, installed as specified by the manufacturer. The traditional angular-rate sensors are rate gyroscopes. Typically, good performance for rate gyroscopes includes: linearity of ± 0.2 to ± 0.5 percent full scale to 1/2 full scale and ± 1 to ± 2 percent to full scale; cross-axis sensitivity of 0.04 percent; thresholds of 0.05 percent full scale; and hysteresis 0.15 percent full scale. ‘Solid-state’ sensors based on the Coriolis acceleration of vibrating elements, fiber optics, lasers or other principles are also commercially available. These typically have performance properties such as: linearity of ± 0.1 to 1 percent full scale; sensitivity threshold of 0.01 percent and zero hysteresis. Angular-rate transducers are typically fixed in the vehicle: therefore, in steady-state turning they measure earth-plane yaw velocity multiplied by the cosine of the vehicle roll angle. The signal must be corrected for vehicle roll and pitch angles in order to obtain yaw velocity in the earth plane. When sideslip transducers are installed at both front and rear, yaw velocity in the earth plane can be computed from the difference between front and rear lateral velocities, divided by the longitudinal distance between the transducers.

7.6 Lateral Acceleration

In most manoeuvres, particularly in steady state, the quantity of interest is centripetal acceleration. In practice, lateral acceleration is the quantity that is typically measured. Centripetal acceleration can be determined from lateral acceleration if other vehicle motion variables are also known. Lateral acceleration (*aY*) can be measured by an accelerometer having sufficient accuracy over a sufficient bandwidth, which includes steady state, and installed in one of the following ways:

a) Mounted on the sprung mass and aligned with its sensitive axis aligned with the vehicle *Y*V axis. If it is not located at the origin of the vehicle axis system, its output will have an error due to yaw, roll and pitch accelerations. Although this error should not exist under steady-state conditions, the accelerometer location should be recorded. The position-corrected signal will measure 'side acceleration', which in turn must be corrected for the component of gravitational acceleration due both to the sine of the vehicle roll angle plus that of track surface inclination.

b) Mounted on a platform stabilized by a gyroscope system: Position correction considerations are as in a), above. Consideration must be given to gyro erection and drift errors, as described below:

An accelerometer mounted to the vehicle sprung mass, as in a) and b) above, will measure the lateral acceleration of the sprung mass. In steady state, this will be equivalent to the lateral acceleration of the total vehicle. High quality 'servo' accelerometers have linearities of ± 0.05 to ± 0.1 percent full scale, with 0.02 percent hysteresis and 0.001 percent resolution. Accelerometers based upon measurement of beam or spring deflection typically have linearities of ± 1 percent of full scale. Measurement errors can be dominated by installation conditions: for example, a 0.6° error in roll angle compensation will cause a 0.01 *g* acceleration measurement error. Steady-state centripetal acceleration may be obtained as the product of horizontal velocity and yaw velocity. Steady-state centripetal acceleration differs from lateral acceleration by the cosine of the vehicle sideslip angle. This correction factor may be applied in data processing, or for sufficiently small sideslip angles (for example; cosine 8° is 0.99), the difference may be ignored. When travelling in steady state on a known radius, centripetal acceleration may be obtained from horizontal velocity squared divided by the circle radius or from yaw velocity squared multiplied by the radius. For these methods of determining acceleration, 'radius' should ideally be the radius of the circular path of the reference point, including corrections for body roll, etc. Practically, such errors may have to be tolerated.

NOTE — The side acceleration is the component of the vector acceleration of a point in the *Y*-direction.

7.7 Body Angles

Vehicle roll and pitch angles with respect to the gravity vertical can be measured by a two-axis gyroscope, either a case-referenced free gyro or a gravity-referenced vertical gyro. The free-gyro element is caged, or locked to its case when not measuring. When uncaged, it remains fixed in inertial space, enabling measurement of angular vehicle motion. A free gyro may be used to measure roll and yaw, or roll and pitch motion. A vertical gyro is 'erected' to a gravity vertical by pendulous switches, which when activated control slow-acting torquer motors. Neither type can maintain the required measurement accuracy for long periods of steady turning. Free gyros and vertical gyros with deactivated erection systems tend to 'drift' at a rate usually specified by the manufacturer at 0.5° to 1° per minute maximum; and vertical gyros with activated erection systems seek an 'apparent vertical', which is the sum of the gravity and lateral acceleration vectors, at a rate of 2° to 5° per minute. In the absence of lateral acceleration, the accuracy of vertical-gyroerection is typically specified at ± 0.15° to ± 1°. Vehicle roll and pitch angles with respect to the road surface can be measured by:

a) An angular measurement transducer installed in the roll and pitch gimbals of a sideslip trolley;

b) Measurement of changes in the vertical distance to the ground from reference points on either side and/or the front and rear of the vehicle, by ultrasonic or optical transducers. The accuracy of the ultrasonic or optical transducers of ± 0.5 mm is sufficient, taking into account that the pavement reference surface is far from being flat and its roughness is quite noticeable. Fitment of three transducers to the vehicle will define a plane that can be used to compute both pitch and roll angles relative to the road surface. It is recommended to fit the ultrasonic or optical transducers as far apart as possible in order to improve measurement accuracy; and

c) Measurement of wheel jounce and rebound motion with respect to the sprung mass, taking into account suspension linkage factors. (This method will not account for tyre deflections.) In each of these methods, it is practical to attain the specified accuracy, with no restriction on test run duration.

To obtain vehicle roll and pitch angles relative to the earth plane, the signal must be corrected for the angle of the road surface relative to horizontal.

The change in vehicle roll and pitch angles from an initial test condition can be measured by integration of the signals from an angular-rate gyros. This method is suitable only for short tests since the entire signals, including any zero offsets, will be integrated.

NOTES

1 In vehicles with suspended cab or separated cab to the chassis there could be two body angles. One of the cab relative to the road surface and the other of the chassis relative to the road surface.

2 The measurements of changes in the vertical distance to the road surface from reference points on either side of the vehicle by ultrasonic or optical transducers to measure roll angle may give different results than other methods, depending on vehicle chassis roll stiffness. This effect could be noticeable in vehicles with separated chassis or very long vehicles. Use of roll angle data obtained with respect to the test surface or to gravity should be corrected for road surface inclination, according to the end usage.

7.8 Steering-Wheel Torque

Steering-wheel torque is measured by a torque load cell, installed as specified by the manufacturer to measure the torque applied to the steering wheel about its axis of rotation. In some tests, the results are not valid if the steering-wheel inertia is not the original one.

7.9 Steer Angles

Steer angles of the wheels with respect to the sprung mass can be obtained by angle measurement transducers, attached between the sprung mass and spindle assemblies; mounted in bearings to the wheel hubs and attached to the sprung mass through restraints which permit unrestricted fore/aft, vertical, and camber motions; or by linear or angular displacement transducers mounted in the steering linkage. The resultant front-wheel steer angle resulting from force and moment compliance plus suspension kinematics is computed by subtracting steering-wheel angle divided by overall steering ratio from total front road-wheel steer angle. Resultant rear-wheel steer angle resulting from force and moment compliance plus suspension kinematics is the same as rear road-wheel steer angle, except for vehicles having four-wheel steering.

7.10 Slip Angles

Tyre slip angles can be measured directly by available optical transducers. Alternatively, they can be computed as the difference between sideslip angle referred to the front and rear wheel locations and the respective total road-wheel angles.

7.11 Vehicle Trajectory

The vehicle trajectory can be measured by a Global Positioning System (GPS). The GPS provides a simple non-contact measurement of speed and both X and Y position in the earth-fixed coordinate system. Sampling update rate is usually 20 Hz. Resolution of X and Y coordinate changes into course angle can be performed in post-processing or within some commercially available units. Some commercial units provide both analogue and digital outputs. Typical speed accuracy is 0.1 km/h, with resolution to 0.01 km/h. Typical distance resolution is 1 cm. Typical course angle accuracy is 0.1°, with resolution of 0.01°. Trajectory can be determined by integration of X and Y velocity components or directly from X and Y displacements. Sideslip angle can be computed from the X and Y velocities, or from the difference between course angle and the integrated signal from a vehicle-fixed yaw rate gyro. The defined accuracy of GPS is valid only for steady-state conditions.

ANNEX A

(*Clause* 5.4.4)

(VEHICLE INFORMATION)

Vehicle identification

Vehicle identification number	………………………………………………………
Type of vehicle	………………………………………………………
Manufacturer	………………………………………………………
Model	
Model Year	………………………………………………………
Registration Number	………………………………………………………

Drive train

Type of Drive	☐ FWD ☐ RWD ☐ AWD ☐ 4WD ☐ Others
Special Features (TCS)	………………………………………………………

Engine

Engine Number	………………………………………………………
Type of engine	☐ Gasoline ☐ Diesel ☐ Others ( )
Air/Fuel mixture control	☐ Carburetor ☐ Injection ☐ Others ( )
Charging system	☐ Natural aspirated ☐ turbo charger ☐ Super charger ☐ Others ( )
Ignition point control	☐ Mechanical Electrical
Fuel cut-off	☐ Yes ☐ No
Displacement in Liters/No of cylinders	/
Max power in KW/Engine Speed in RPM	/
Max torque in Nm/engine speed in RPM	/

Transmission

Type of gears	☐ Manual ☐ Automatic ☐ Continuously Variable ☐ Others ( )
If manual (Number of forward gears)	………………………….. gears

Gear ratios

1st Gear	…………….: 1
2nd Gear	…………….: 1
3rd Gear	…………….: 1
4th Gear	…………….: 1
5th Gear	…………….: 1
6th Gear	…………….: 1
Reverse Gear	…………….: 1

Final Drive Ratio

Final Drive ratio	……………. : 1

Suspension

Front Suspension:	☐ Independent ☐ Dependent ☐ Others
Type of front suspension :	....
Front Stabilizer/Anti-roll bar	☐ Yes ☐ No
Rear Suspension:	☐ Independent ☐ Dependent ☐ Others
Type of rear suspension :	....
Rear Stabilizer/Anti-roll bar	☐ Yes ☐ No

Steering

Steered axle	☐ Front ☐ Rear ☐ Both
Type of Steering	☐ Manual ☐ power assisted ☐ Electric ☐ Electronic controlled steering ☐ Others
Type of Electronic power steering (EPS)	☐ Rack Mounted ☐ Column Mounted ☐ Pinion Mounted ☐ Others ( )
Overall steering ratio on Front/Rear	....
Steering wheel diameter in (mm)	....
Max steering wheel angle in (deg)	....
Turning circle radius in (m)	....

Braking system

Power assisted	☐ Yes ☐ No
Antilock brake system	☐ Yes ☐ No
Electronic stability system	☐ Yes ☐ No if Yes ☐ on ☐ off
Mention other features (If any)	....
Type of front axle brake	☐ Drum ☐ Disc ☐ Others
Type of rear axle brake	☐ Drum ☐ Disc ☐ Others

Wheel

Rim size-Front, in Inch	
Rim Offset (Front), mm	
Type of RIM	☐ Steel ☐ Alloy
Rim size-rear, in inch	....

Tyres

Tread depth-Front/Rear (New) (Optional)	.... mm/ .... mm
Aspect ratio-Front/Rear	.... / ....
Inflation pressure-front/Rear	.... kPa / .... kPa

Mass	Kerb weight of the vehicle	Total:…………kg / FAW: …………….kg / RAW : ……………kg
	Gross vehicle weight of the vehicle	Total:…………kg / FAW: …………….kg / RAW : ……………kg
	Weight during testing condition(instrumentation/driver)	Total:…………kg / FAW: …………….kg / RAW : ……………kg
	Weight during testing condition (instrumentation/driver)-Split up	FL:…………kg, FR…………..kg, RL:…………kg, RR………..…kg,

Vehicle Dimensions	Overall height, mm	....
	Overall width, mm	....
	Overall length, mm	....
	Wheel base,mm	....
	Track width front, mm	....
	Track width rear, mm	....
	CG height at test mass, mm	....

General comments and/or relevent details:
....
....
....

ANNEX B

(*Clause* 5.4.4)

TEST CONDITION

Test method

Proving ground

Vehicle Identification Number	....
IS Number / Test Method	.... / ....
location	....
Path radius	....
Odometer Reading in kms	Start: .... / End : ....

Ambient condition road surface

Type	....
Condition	....
Track temperature, degree celcius	....
Co-efficient of friction between tyre & road, Mue	....

Climate

Air temperature, degree celcius	....
Relative humidity, percent	....
Wind speed, m/s	....
Wind direction	....

Tyres

Manufacturer name	....
Date of mfg	Front………………. Rear…………mm
Tyres pecification	Front .... Rear ....

Driving conditions

Manual transmission	Engaged gear:…………Gear
Automatic transmission	Gear selector position:…………..

Staff

Test Engineer	....
Observer	....
Data analyst	....

Test method specific data:

....

....

....

Reference point co-ordinates for measured variables:

X_v = mm (Measured from, front left wheel center point along the longitudinal axis of vehicle)
Y_v = mm (Measured from front left wheel center point along the lateral axis of vehicle)
Z_v = mm (Measured from, front left wheel center point along the verticle axis of vehicle)

Sensor positions (referred to the reference point)			
Variable	**X (mm)**	**Y (mm)**	**Z (mm)**
Longitudinal velocity			
Lateral velocity			
Sideslip angle			
Longitudinal acceleration			
Lateral acceleration			
Yaw velocity			
Pitch velocity			
Roll velocity			

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